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GAILLIMH

NATIONAL UNIVERSITY OF IRELAND
GALWAY

SEMESTER 2 (SUMMER) EXAMINATIONS 2000

3rd Year B.Sc. Unit EP314 (Repeat) : Thermodynamics

Experimental Physics

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Time allowed : TWO hours
Answer THREE questions

Q.1(a) (i) State the Clausius principle (i.e. the version of the second law of thermodynamics in terms of entropy)

(ii) Justify the statement: "The change in entropy for a system which proceeds from state 1 to state 2 is independent of the path taken, i.e. whether the process is reversible or irreversible."

(b) (i) 1 kg of water at 0 °C is brought into contact with a large heat bath at 100 °C. When the water has reached 100 °C, what has been the change in entropy of the water, the heat bath, and the entire system? ($C_{water} = 4190\ \mathrm{J\ kg^{-1}\ {}^{\circ}C^{-1}}$).

(ii) If the water has been heated from 0 °C to 100 °C by first bringing it in contact with a heat bath at 50 °C and then with one at 100 °C, what would have been the change in entropy of the entire system?

(iii) How would you make the process of heating the water to 100 °C reversible ?

Q.2(a) (i) Explain what the throttling (Joule-Thomson) effect is ? What quantity is conserved in this process ? Draw a graph of T vs. P for this process. Define the Joule-Thomson coefficient. Explain what the terms 'inversion curve' and 'maximum inversion temperature' mean and what is their physical significance. What is the Joule-Thomson coefficient for an ideal gas ?

(ii) How can the throttling process be used in the liquefaction of gases?

(b) One kilomole of an ideal gas undergoes a throttling process from 4 atm to 1 atm. The initial temperature of the gas is 50^0C. Determine

(i) The temperature change.

(ii) The work done on and the heat added to the gas.

(iii) Using the fact that $\Delta S = \int \delta Q/T$ find the entropy change ΔS of the gas. Comment on your result.

Q.3(a) Give a detailed description of the operation of a diffusion pump.

(b) Give a detailed description of how a McLeod gauge operates. Show how the pressure is calculated – include a formula. Include a list of some of its advantages and disadvantages.

Q.4(a) (i) Write down the Clausius-Clapeyron equation and explain what each term in the equation represents.
(ii) The Clausius-Clapeyron equation relates to what kind of phase transition ? Make an argument to justify your choice of phase transition type.
(iii) Write down two versions of the third law of thermodynamics, and give examples of two physical implications of this law which can be tested experimentally.

(b) (i) 0.025 kg of liquid He_4 at its boiling point (4.0 K at 1 atmosphere) is contained in a Dewar vessel whose thermal capacity may be neglected. Calculate the percentage of the liquid that is evaporated when a small silver sphere of mass 0.35 kg and at a temperature of 20 K is placed in the liquid helium. The specific enthalpy of vaporisation of the liquid He_4 is 2.1×10^4 J/kg and below 20 K the specific heat capacity of silver $C_p = (1.5 \times 10^{-4})T^3 + (6.0 \times 10^{-3})T$.
(ii) He_4 remains a liquid down to 0 K at 1 atmosphere, but becomes a solid at sufficiently high pressures. The density of the solid is greater than that of the liquid. Consider the phase-equilibrium line between the solid and liquid. In the limit $T \rightarrow 0$, is the slope P vs. T positive, negative, or zero ?

Q.5(a) (i) Define the following terms: *microstate*, and *statistical* weight Ω.
(ii) What is the postulate of equal a priori probabilities and what is its significance ?
(iii) Consider a system of N dipoles. Of these n are aligned parallel to a magnetic field and the remaining are aligned anti-parallel to the field. What is the statistical weight of this state if the dipoles obey quantum statistics ? You must explain your reasoning and not just write down a formula.

(b) Consider a system of 4 distinguishable particles. The energy level of each particle are $0, 3\varepsilon, \ldots\ldots$ The total energy of the system is 6ε. Identify the possible distributions, evaluate Ω and work out the average distribution of the four particles in the energy states – i.e. on average how many particles are there in each energy level.